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# EFFECT OF FERTILIZERS ON THE PHYSICAL AND CHEMICAL PROPERTIES OF WHEAT

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The quality of wheat is of importance commercially, not only to the miller and baker, but to the producer as well. The miller prefers wheat of good weight per bushel, which will give yield and strength of flour; the quality of flour, which in turn is dependent to a certain extent upon the composition of the wheat from which it is milled, is a matter of consequence to the baker.

When associated with increased yields, any factor which tends to bring greater values may be considered well worth the attention of those interested in the production of this crop. The properties of the wheat grain, aside from those caused by variation in the wheat plant itself, are the results of environment, including localized climatic conditions and soil fertility.

Numerous citations can be made from the voluminous literature giving the results of investigations on this subject, which show that the character of wheat is changed to a greater extent by seasonal influences than by differences in soil. For this reason there is a tendency to regard the influence exerted by soils and fertilizers as one of minor consideration. However, meteorological conditions cannot be controlled, while the fertility of soils adapted to the growing of wheat can be improved and maintained. Therefore, it would seem that, applied to local conditions, this phase of the subject is of equal, if not greater, importance than that referring to season and climate.

This bulletin presents information relative to the changes induced by different chemical conditions of the soil which may have a bearing on the quality of wheat; the term "quality" is used as referring to both the physical characteristics and chemical composition of the grain. The included data were obtained from analyses of wheat grain, harvested in the year 1910 from differently treated plots of soil on which the fertility investigations of this Station have been conducted since 1894. The same variety of wheat is grown on these plots, which are located on soil differing only in its crop producing capacity, as influenced by fertilizers and manures.

## PHYSICAL VARIATIONS

A decided variation in the appearance of wheat grain harvested from plots of soil treated with various forms of fertilizers is noticeable each season. This is more pronounced for years in which the soil moisture and other factors are favorable for a good crop than when reverse conditions prevail. For the purpose of obtaining a quantitive comparison of the differences observed, the grain from the several plots included in this investigation was graded into two classes, according to its physical appearance. A fifty-gram sample of wheat was used. The plump and shriveled or incompletely filled kernels were separated by hand and the percentages of each determined.

TABLE I—Showing the fertilizers applied per acre, the percentage of plump and shriveled kernels and the yield of wheat per acre for the year 1910

| Plot No | Fertilizers applied during one 5 year rotation | | | | Percentage of plump kernels | Percentage of shriveled kernels | Yield per acre for 1910 |
|---|---|---|---|---|---|---|---|
| | Acid phosphate | Potassium chloride | Dried blood | Nitrate of soda | | | |
| | Lbs | Lbs | Lbs | Lbs | | | Bushels |
| 0 | | | | | 51 | 49 | 8 45 |
| 3 | | 260 | | | 66 | 34 | 10 33 |
| 5 | | | 50 | 440 | 40 | 60 | 10 75 |
| 9 | | 260 | 50 | 440 | 51 | 49 | 13 00 |
| 2 | 320 | . | | | 88 | 12 | 20 33 |
| 6 | 320 | | 50 | 440 | 79 | 21 | 25 25 |
| 8 | 320 | 260 | | | 88 | 12 | 19 75 |
| 11 | 320 | 260 | 50 | 440 | 81 | 19 | 27 00 |
| 12 | 320 | 260 | 50 | 680 | 84 | 16 | 28 33 |
| 30[1] | (1) | 260 | (1) | (1) | 87 | 13 | 29 25 |
| 18- | (2) | (2) | (2) | (2) | 87 | 13 | 33 42 |
| a | | | | | 94 | 6 | 34 15 |

0 Unfertilized
[1] Phosphorus and potassium supplied by tankage containing 6 percent nitrogen and 6 percent phosphorus
[2] The three elements supplied by barn yard manure, 8 tons on corn and 8 tons on wheat
a Elements supplied by 10 tons of manure with the addition of 400 pounds of untreated rock phosphate for the corn crop, and a fertilizer on wheat consisting of steamed bone meal 100 pounds, acid phosphate 130 pounds, potassium chloride 20 pounds, sodium nitrate 50 pounds. The sodium nitrate is applied broad-cast over the wheat in April.

The accompanying illustrations show the appearance of the grain grown on the differently treated soils, and at the same time represent the percentages of the separated portions as indicated by the numbers on the circumference of the illustrations. The wheat kernels as shown are reduced to two-thirds their original size.

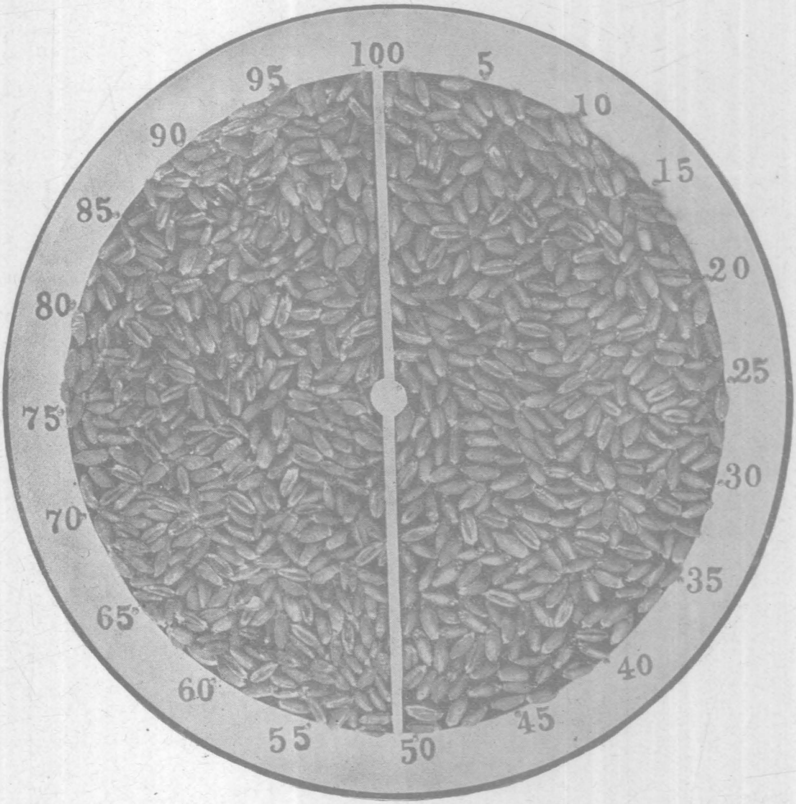


Fig. 1. Soil Treatment—none:
Yield per acre 8.45 bushels.

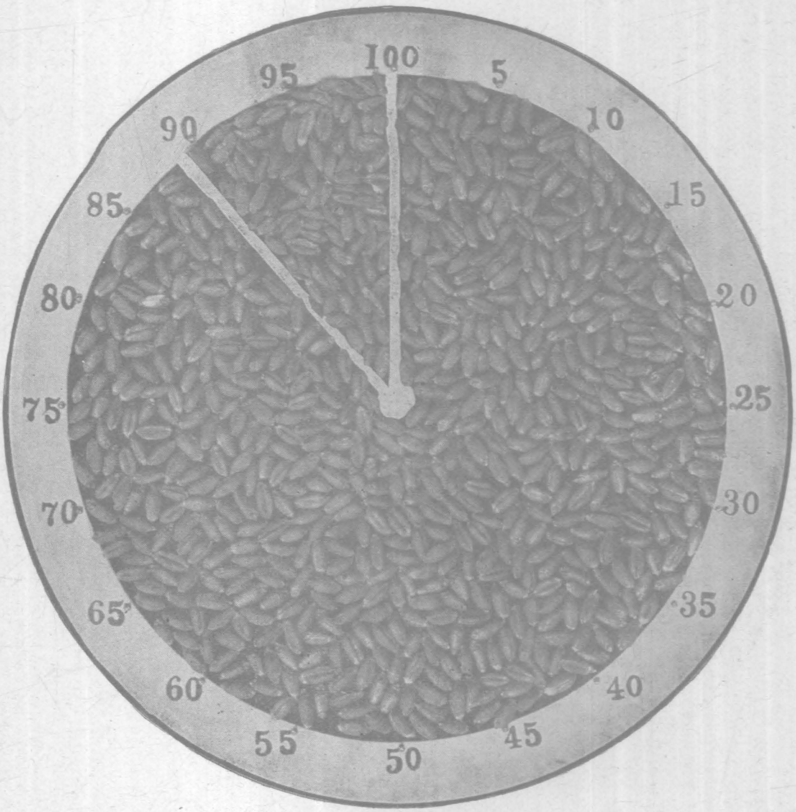


Fig. 2. Soil Treatment for one 5-year Rotation: Phosphorus 20 pounds, carried by acid phosphate. Yield per acre 20.33 bushels.

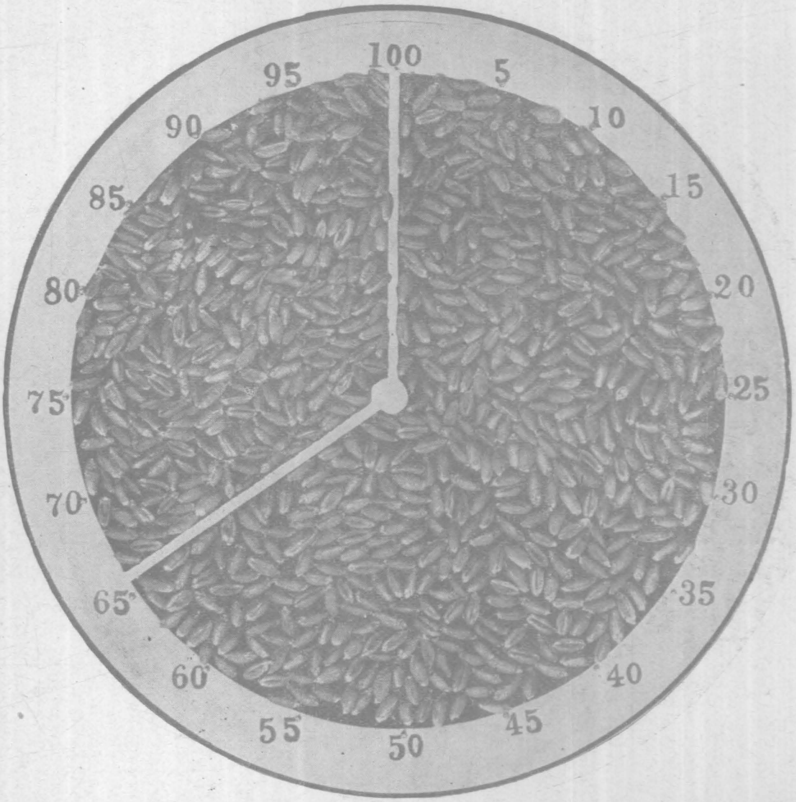


Fig. 3. Soil Treatment for one 5-year Rotation:
Potassium 108 pounds, carried by potassium chloride.
Yield per acre 10.33 bushels.

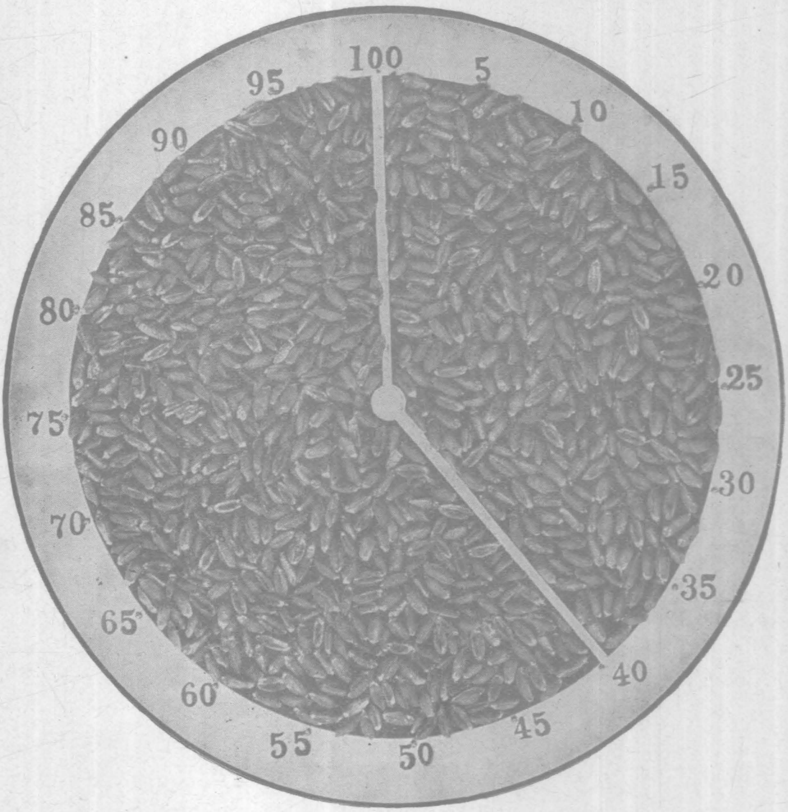


Fig. 4 Soil Treatment for one 5-year Rotation: Nitrogen 76 pounds, carried by sodium nitrate. Yield per acre 10.75 bushels.

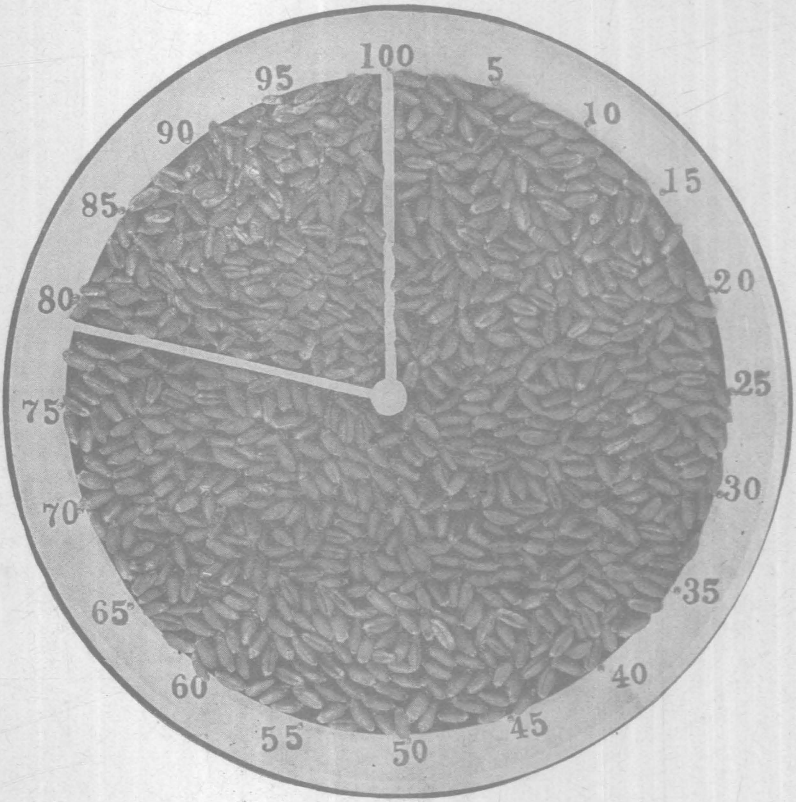


Fig. 5. Soil Treatment for one 5-year Rotation: Phosphorus 20 pounds and nitrogen 76 pounds, carried by acid phosphate and sodium nitrate. Yield per acre 25.25 bushels.

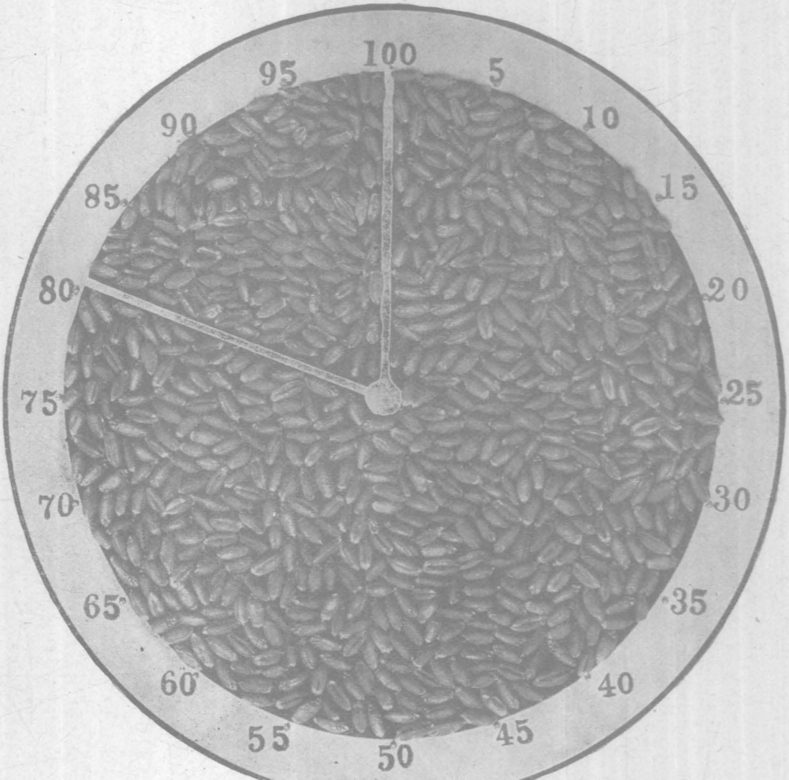


Fig. 6. Soil Treatment for one 5-year Rotation:
Phosphorus 20 pounds; potassium 108 pounds; nitrogen 76 pounds, carried by acid phosphate, potassium chloride and sodium nitrate.
Yield per acre 27 bushels.

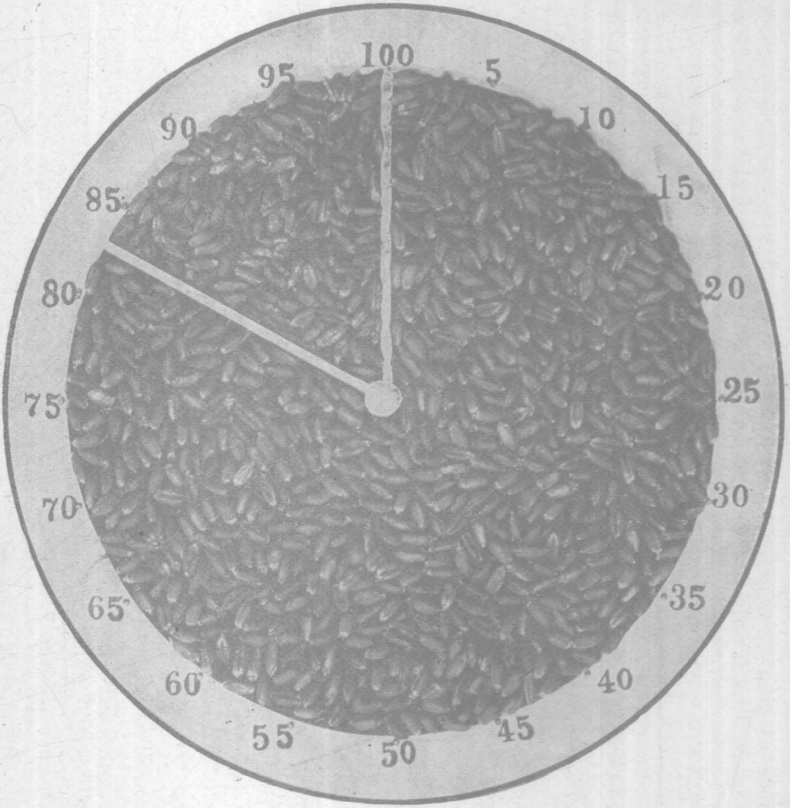


Fig. 7. Soil Treatment for one 5-year Rotation: Phosphorus 20 pounds; potassium 108 pounds; and nitrogen 114 pounds; carried by acid phosphate, potassium chloride and sodium nitrate. Yield per acre 28.33 bushels.

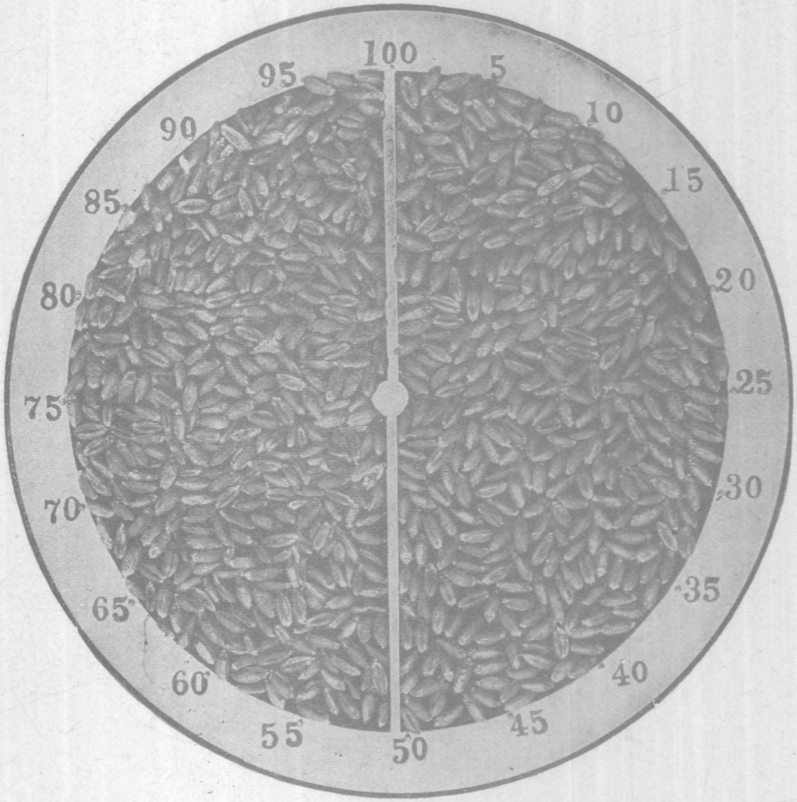


Fig. 8. Soil Treatment for one 5-year Rotation:
Potassium 108 pounds; and nitrogen 76 pounds; carried by potassium chloride and sodium nitrate.
Yield per acre 13.00 bushels.

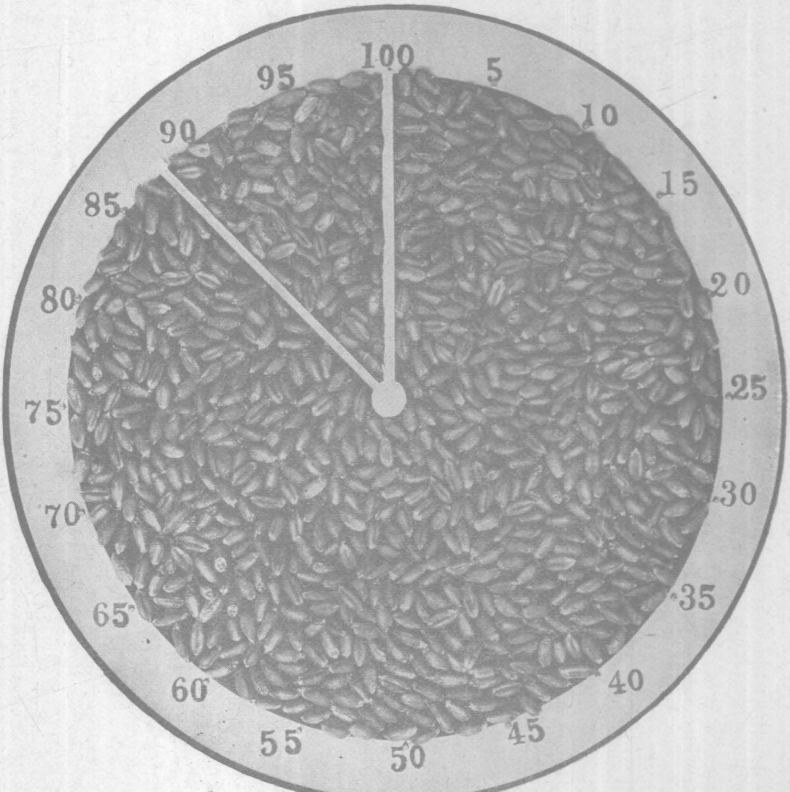


Fig. 9. Soil Treatment for one 5-year Rotation: Phosphorus 20 pounds and potassium 108 pounds; carried by acid phosphate and potassium chloride.

Yield per acre 19.75 bushels.

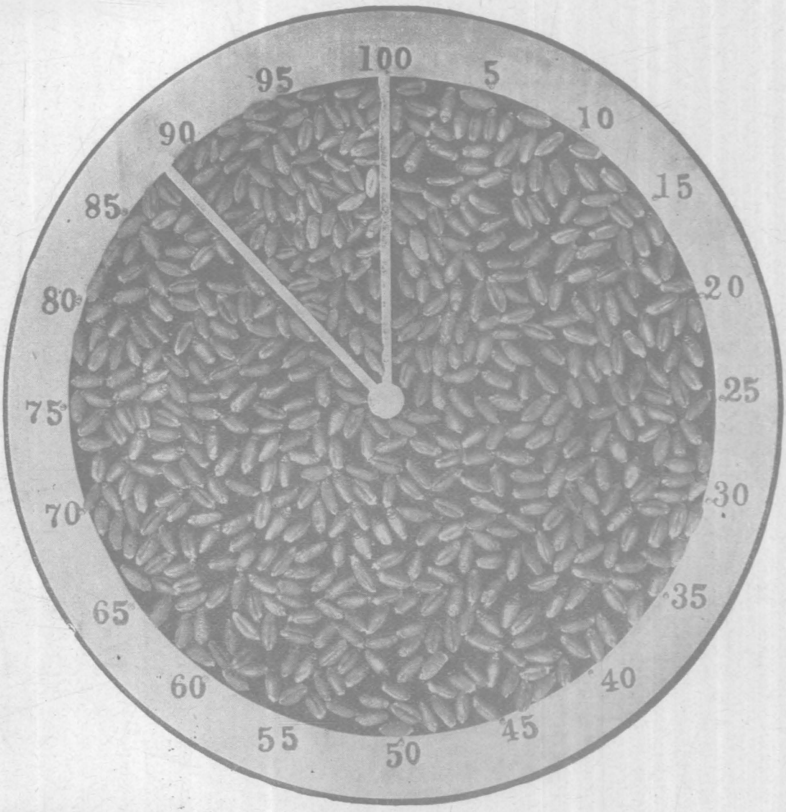


Fig. 10. Soil Treatment for one 5-year Rotation: Phosphorus 48 pounds; potassium 112 pounds, and nitrogen 114 pounds; carried by yard manure. Yield per acre 33.42 bushels.

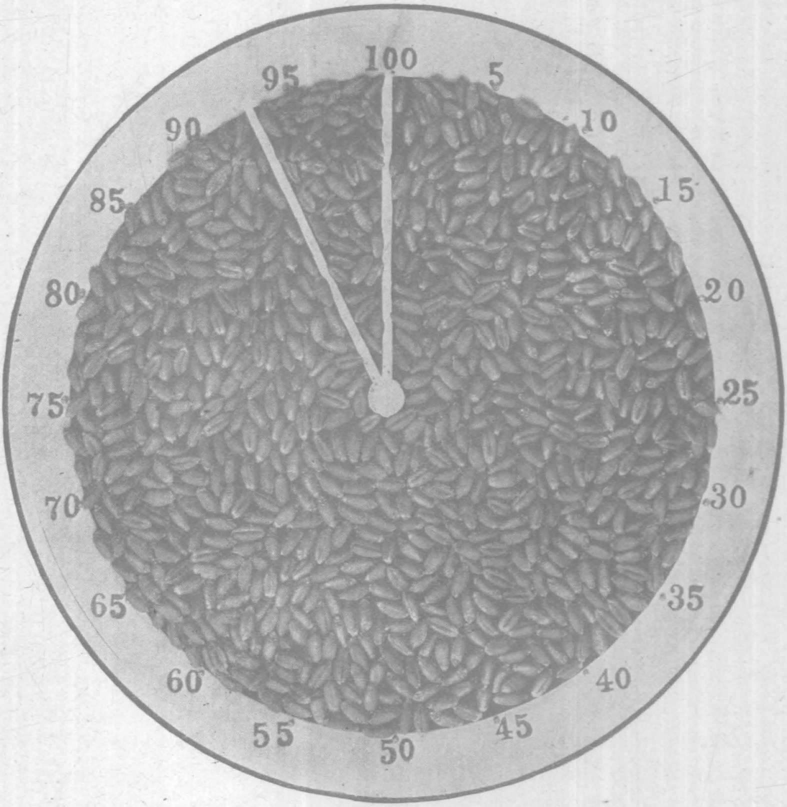


Fig. 11. Soil Treatment for one 4-year Rotation: Phosphorus 112 pounds; potassium 81 pounds; nitrogen 112 pounds; carried by 10 tons manure and 450 pounds phosphate rock on the preceding corn crop, and acid phosphate, steamed bone meal, potassium chloride and sodium nitrate on the wheat.

Yield per acre 34.15 bushels.

Table I on page 568, which summarizes these data, also gives the fertilizer treatment and yield per acre for the several differently fertilized plots. The type of wheat grown on unfertilized soil which has produced the minimum amount of grain is shown by Figure 1.

The fertility investigations on this particular soil have demonstrated that fertilizers containing phosphorus are most efficient in producing yield of grain. Only slightly increased yields follow the use of either potassium or nitrogen when used singly as soil amendments. The yields of wheat from Plot 3, treated only with muriate of potash, and from Plot 5, with nitrate of soda only, were practically the same for the year 1910, although average results for 17 years show that the return from nitrogen has been slightly greater than that obtained from potassium. Where both of these elements are applied in combination, the yield has not been as large as where phosphorus alone is applied.

Comparing the three Figures, 2, 3, and 4, which illustrate the character of the grain secured from Plots 2, 3 and 5, the soil treatment for each of the plots being in the order designated, acid phosphate, potassium chloride (muriate of potash), and nitrate of soda, it will be observed that there is a more striking difference in the type of kernels produced by these different conditions of fertilization than is indicated by the yields obtained.

It is also apparent that phosphorus has effected the physical appearance of the grain to a greater extent than either potassium or nitrogen. With reference to this marked change in the character of the grain from the soil where phosphorus is applied, attention is called to the chemical composition of the wheat, which is referred to more fully in another connection. The results show that the carbohydrate content of the grain is generally higher where the proportion of phosphorus in the fertilizer is greater than that of the nitrogen; and, on the other hand, the percentages of nitrogen are highest in the case of the wheat grown without an adequate supply of phosphorus at its disposal.

The wheat grown on soils to which phosphorus is added matures earlier than either the crop harvested from the unfertilized soil, or that furnished with potassium or nitrogen without phosphorus. Nitrogen and phosphorus seem to exert opposite influences upon plant growth; nitrogen accelerates vegetative growth and prolongs the period of seed development, while phosphorus tends to hasten maturity and favors seed development.

Increasing the nitrogen supply, without increasing the potassium and phosphorus, has lowered the quality of the grain on Plot 5 below that grown on the untreated soil, although the yield has been slightly increased. Potassium has improved the quality so far as plumpness of the kernel is concerned, and at the same time has caused a small increase in yield. The appearance of the grain grown under this condition of fertilization is shown in Figure 3.

Numerous investigations made by plant physiologists show that potassium performs an important function in the formation of carbohydrates. The percentages of starch and sugars found in the grain grown on the unfertilized soil and on that treated with potassium are practically the same. A comparison of the proportions of plump and shriveled grain found on these two plots with the chemical composition found in each case, indicates that the shriveled condition of the kernels is not entirely due to a decreased formation of carbohydrates.

When both phosphorus and nitrogen, either with or without the addition of potassium, are applied, (Plots 6, 11 and 12, Figures 5, 6 and 7) there is a close agreement in the proportion of well filled kernels in each lot of wheat, although slightly higher percentages of plump kernels are found in the wheat from Plots 11 and 12, where potassium is used in combination with phosphorus and nitrogen.

The quality of wheat grown on the soil of Plot 9, where potassium and nitrogen are used in combination without phosphorus, is illustrated by Figure 8. Here the increased quantity of potassium in the soil has offset the influence exercised by nitrogen when used alone on the soil of Plot 5, and the resultant effect, so far as appearance is concerned, is the same as that produced by the unfertilized soil, although the yield of grain is somewhat larger on the soil fertilized with potassium and nitrogen. On Plot 8 (Fig. 9), where phosphorus and potassium in combination, without nitrogen, are the fertilizing elements added to the soil, the addition of potassium has produced no different effect from that caused by phosphorus only. The proportion of plump kernels and the composition and yield of grain are approximately the same for Plot 8 as for Plot 2, which is treated with phosphorus alone.

A maximum yield of grain has been produced, on another part of this farm, (soil designated "a" in the tables) which was originally of the same fertility as that on which the several other described wheats were grown. This soil has been brought to a high state of fertility by the use of chemical fertilizers and manure, carrying approximately 112 pounds of phosphorus, 81 pounds of potassium and 103 pounds of nitrogen per acre. The system of fertilization followed has been 10 tons of manure, treated during accumulation with 400 pounds of rock phosphate, for the corn crop, and 400 pounds of a mixture of acid phosphate, steamed bone meal, potassium chloride and nitrate of soda, containing approximately 3 percent of nitrogen and potassium and 7 percent phosphorus ( or 4 percent "ammonia", 16 percent "phosphoric acid" and 4 percent "potash") for the wheat crop following the oat crop in a four-year rotation of corn, oats, wheat and clover. This wheat is illustrated in Figure 11 and stands out clearly in a class by itself, not only in the greater proportion of plump grain, but also in the uniformly well developed condition of the wheat.

## VARIATION IN COMPOSITION

Table II gives the percentages of starch and soluble carbohydrates (sugar and dextrin), with protein and phosphorus found in the different lots of wheat previously described.

TABLE II: Showing total amount of starch and soluble carbohydrates, protein and phosphorus content of wheat grown on soil differently fertilized

| Plot No. | Fertilizing elements per acre for one 5-year rotation | | | Percentage composition of grain | | | Yield per acre West End 1910 |
|---|---|---|---|---|---|---|---|
| | Phosphorus | Potassium | Nitrogen | Starch and soluble carbohydrates | Protein | Phosphorus | |
| | Lbs. | Lbs. | Lbs. | Percent | Percent | Percent | Bushels |
| 0 | .. | ... | . . | 60 04 | 14 50 | .3222 | 8.45 |
| 3 | .. | 108 | ... | 60 39 | 14.75 | .3399 | 10.33 |
| 5 | .. | . . | 76 | 58.37 | 15 81 | .3217 | 10.75 |
| 9 | | 108 | 76 | 58 23 | 15 88 | .3112 | 13.00 |
| 2 | 20 | ... | ... | 64.10 | 12 56 | .3777 | 20 33 |
| 6 | 20 | . | 76 | 61 99 | 13 94 | .3318 | 25 25 |
| 8 | 20 | 108 | . . | 64.25 | 12 00 | .3954 | 19 75 |
| 11 | 20 | 108 | 76 | 61.16 | 13 88 | .3376 | 27 00 |
| 12 | 20 | 108 | 114 | 60 80 | 14 69 | .3262 | 28.33 |
| 30[1] | 30 | 108 | 38 | 64.46 | 12 88 | .3993 | 29.25 |
| 18[2] | 48 | 112 | 144 | 64.04 | 11.44 | .4253 | 33.42 |
| a | 112 | 81 | 103 | 64.56 | 12.32 | .4358 | 34 15 |

0 Unfertilized.
[1] Phosphorus and potassium supplied by tankage containing 6 percent nitrogen and 6 percent phosphorus.
[2] The three elements supplied by barn yard manure, 8 tons on corn and 8 tons on wheat.
a Elements supplied by 10 tons of manure with the addition of 400 pounds of untreated rock phosphate for the corn crop; and a fertilizer consisting of steamed bone meal 100 pounds; acid phosphate 130 pounds; potassium chloride 20 pounds; sodium nitrate 50 pounds. The sodium nitrate is applied broadcast over the wheat in April.

The addition of phosphorus alone, to the soil of Plot 2, is followed by an increased amount of carbohydrates and a lowering of the protein percentage in the grain.

It will be observed that the carbohydrates and phosphorus on the one hand, and the protein on the other, bear a certain complementary relation to each other. A high percentage of carbohydrates is always accompanied by a high percentage of phosphorus, while the protein and carbohydrates stand in an inverse ratio to each other.

Data previously published, (Bulletin 221, Ohio Exp. Sta.), on the composition of wheat, show the same relation between the phosand phorus nitrogen content of the wheat crops grown in three different seasons.

The effect produced on the character of the grain by an unbalanced ratio of phosphorus and nitrogen has already been referred to under the discussion of the physical variation. The result of this adverse condition is further shown by the composition of the grain grown on the soil of Plot 5 and Plot 9, where more nitrogen is applied than can be utilized to the best advantage, on account of a lack of available phosphorus. The wheats from these two plots are similar in composition and have the highest percentage of protein and the lowest carbohydrate content of any of the wheats analyzed. The high protein percent in the grain from Plot 5, compared with the physical character of the grain, as shown in Figure 4, strikingly shows the relation between the shriveled condition of the grain and its nitrogen content.

The composition of the grain from Plot 3, supplied with potassium in the form of potassium chloride, does not differ from that grown on unfertilized soil, although the yield has been slightly increased and the physical appearance of the grain improved to some extent.

Further evidence of the fact that potassium has not effected the composition of the grain is shown by the results for Plot 8, which is fertilized with phosphorus and potassium; the composition, yield and physical appearance of the grain from Plot 2, treated with phosphorus only, and that from Plot 8 are similar.

While the chemical composition of the grain does not show an increased percentage of carbohydrates following the use of potassium, this element has in some manner evidently contributed toward plumpness of grain. This may be due to the distribution of starch or to changes in the cellular arrangement of the wheat kernel.

The heaviest yielding plots are those to which both phosphorus and nitrogen have been added. In some instances these elements have been supplied by mineral carriers, acid phosphate and nitrate of soda, and in others by the organic materials, manure and tankage.

A comparison of the results obtained for the several plots receiving phosphorus and nitrogen shows that changes in the composition are due either to the ratio of phosphorus to nitrogen, to the different carriers used, or to a combination of these two conditions.

Considering first the effect of difference in proportion of phosphorus and nitrogen, a comparison between Plots 6 and 11, where the same quantities of these elements are applied, and where the ratio of phosphorus to nitrogen is 1 to 3.8, shows that the composition of the grain is very similar. Increasing the quantity of nitrogen, as in the case of Plot 12, so that the ratio is 1 to 5.7, has caused an enhanced accumulation of protein and a decreased amount of carbohydrates and phosphorus in the wheat, but has produced no marked physical change in the grain. On Plot 30 and soil designated (a), the ratio of phosphorus to nitrogen is approximately 1 to 1, and on Plot 18, 1 to 3. The composition of the wheat from these areas corresponds practically with that grown on Plot 2, to which only phosphorus has been added, but the yields are much greater.

From an analysis of the several conditions of soil treatment responsible for the differences noted in the physical character and the composition of the grain, it is evident that the production of a maximum yield, together with well developed grain, depends not only upon the total amount of available plant food applied, but also upon the ratio of phosphorus to nitrogen available to the crop.

The fertilizing materials applied to Plots 18 (Fig. 10) and 30 are carried entirely by organic carriers; Plot (a), with the exception of the small amount of nitrogen carried by 50 pounds of nitrate of soda, receives all its nitrogen in the organic form. All the remaining plots, with the exception of Plot 0, which is unfertilized, receive their fertilizing elements from an inorganic source.

The three plots to which organic fertilizers are applied yield the largest amounts of grain. A large amount of phosphorus is added to these plots, especially Plot (a), which has produced the largest yield and developed the highest percentage of plump grain. The wheat from this plot contains a large amount of phosphorus and carbohydrates and a small amount of protein, when compared with plots receiving no phosphorus or plots to which only a small amount of phosphorus and a large amount of nitrogen are applied.

It seems that the percentage of phosphorus which is closely associated with the formation of carbohydrates in the grain depends not only upon the amounts of phosphorus and nitrogen applied to the soil, but is also influenced by the form in which the nitrogen is applied. Table III below, which is compiled from results previously published in Bulletin 221, shows how the phosphorus may be increased or decreased by the use of different carriers of nitrogen.

**TABLE III: Effect of mineral and organic carriers of nitrogen on the phosphorus content of wheat grain**

| Fertilizing elements per acre | | | | Carriers of nitrogen | Percent of phosphorus in grain |
|---|---|---|---|---|---|
| Plot | Phosphorus | Potassium | Nitrogen | | |
| | Lbs. | Lbs. | Lbs. | | |
| 17 | 30 | 108 | 38 | Nitrate of soda | .3388 |
| 21 | 30 | 108 | 38 | Linseed oil meal | 3658 |
| 23 | 30 | 108 | 38 | Dried blood | .3650 |
| 24 | 30 | 108 | 38 | Sulfate of ammonia | .3562 |
| 30 | 30 | 108 | 38 | Tankage | .3790 |

The same amounts respectively of the different fertilizing elements are applied to each of the five plots, so that the different percents of phosphorus found must be attributed solely to the effect of the nitrogen carriers. The wheat from Plot 17, where nitrate of soda is used, has the lowest percent of phosphorus in the grain. Sulfate of ammonia, on Plot 24, has produced an increase in phosphorus, while tankage, on Plot 30, has caused the largest amount of phosphorus to be stored in the grain. The cause of this difference in the phosphorus content of the wheat is apparently due to the more retarded assimilation of nitrogen, when this element is supplied by organic carriers than when a more available carrier of nitrogen, like nitrate of soda, is used.

## PROTEIN

Considerable work has been done by those interested in the subject of wheat and flour to establish a basis by which the quality of flour may be determined from the chemical composition of wheat. Results so far obtained by different authorities show that it is primarily a function of the nitrogen containing bodies. The strength of flour is dependent upon the physical character of the gluten and the proportion of the two substances, gliadin and glutenin, from which gluten is formed, when flour is mixed with water, during the process of baking.

The data in Table IV show the percents of gluten and gliadin, percent of gluten in protein and the percent of gliadin in gluten for the several Plots of wheat.

TABLE IV: Total Protein, Gluten, and Gliadin Content of Wheat

| Plot No. | Fertilizing elements per acre for one 5-year rotation | | | Protein | Gluten | Gliadin | Percent of gluten in protein | Percent of gliadin in gluten |
|---|---|---|---|---|---|---|---|---|
| | Phosphorus | Potassium | Nitrogen | | | | | |
| | Lbs. | Lbs. | Lbs. | | | | | |
| 0 | ... | ... | ... | 14 50 | 10.75 | 6.31 | 74.13 | 58.70 |
| 3 | ... | 108 | ... | 14.75 | .... . | 6.75 | ..... | . ... |
| 5 | ... | . . | 76 | 15.81 | 11.81 | 7.38 | 74.70 | 62.17 |
| 9 | ... | 108 | 76 | 15 88 | 12.13 | 7.36 | 76.37 | 61.04 |
| 2 | 20 | ... | ... | 12.56 | 9.38 | 5.13 | 74.68 | 54.69 |
| 6 | 20 | ... | 76 | 13.94 | 9 63 | 6.25 | 69.01 | 64.90 |
| 8 | 20 | 108 | ... | 12.00 | 8.50 | 5.13 | 70 83 | 60.36 |
| 11 | 20 | 108 | 76 | 13.88 | 10 25 | 6.07 | 73.85 | 59.22 |
| 12 | 20 | 108 | 114 | 14.69 | 10.81 | 6.70 | 73.58 | 61 98 |
| 30[1] | 30 | 108 | 38 | 12.88 | 9.44 | 5.59 | 73.30 | 59.22 |
| 18[2] | 48 | 112 | 144 | 11 44 | 8.19 | 4.90 | 71.59 | 59.83 |
| a | 112 | 81 | 103 | 12.32 | 9.13 | 4.94 | 74.11 | 54.11 |

The percentage of gluten, as stated in the table, was calculated from the difference between the total nitrogen and the nitrogen soluble in a 1 percent solution of sodium chloride. This method is not strictly correct on account of the solubility of a small amount of gliadin in the sodium chloride solution, but it is considered sufficiently accurate for the purpose of showing the comparative difference in the wheat. The gliadin was obtained by digesting 5 grams of wheat with 120 cc of 60 percent by volume alcohol for four hours, shaking every 30 minutes and then allowed to stand at room temperature for 13 hours. Nitrogen was determined in an aliquot portion of the filtered solution. The factor 6.25 was used in converting nitrogen to protein.

The percents of gluten and gliadin generally stand in a direct relation to the total protein content; a high percent of gluten in the wheat is accompanied by a correspondingly high percent of gliadin.

There is some variation, however, between the proportions of total protein and the percent of gluten in the protein. The largest amounts of total protein and gluten are found in the wheat from Plot 9, fertilized with potassium and nitrogen.

Although the total protein in the wheats from the productive soil of Plot (a), from Plot 5 treated with nitrogen alone, and from the unfertilized soil, varies considerably, there is in each instance about the same percent of the total protein in the form of gluten.

### CARBOHYDRATES

Table V gives the percents of the several non-nitrogenous substances included under the general term of carbohydrates, including starch, dextrin, dextrose, sucrose, and the cellulose bodies, hemi-cellulose, lignin, and crude fiber.

TABLE V: Carbohydrate content of wheat grown on soil differently fertilized

| Plot No. | Fertilizing elements per acre for one 5-year rotation | | | Percentage composition of grain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Phosphorus | Potassium | Nitrogen | Dextrose | Sucrose | Dextrin | Starch | Hemi-cellulose | Lignin | Crude fiber | Water |
| | Lbs. | Lbs. | Lbs. | | | | | | | | |
| 0 | .. | ... | ... | .03 | 1 34 | 2.91 | 55.76 | 4.91 | 6.04 | 2.71 | 8.76 |
| 3 | ... | 108 | ... | .00 | 1.39 | 3.09 | 55.91 | 5.00 | 6.25 | 2.70 | 8 74 |
| 5 | ... | ... | 76 | .00 | 1.39 | 2.80 | 54.18 | 4.92 | 5.93 | 2.90 | 8.98 |
| 9 | ... | 108 | 76 | .03 | 1.24 | 2.74 | 54.22 | 5.10 | 6.05 | 2.71 | 9.04 |
| 2 | 20 | ... | ... | .02 | 1 30 | 3.37 | 59.41 | 4.40 | 5.72 | 2.51 | 8.65 |
| 6 | 20 | ... | 76 | .12 | 1.42 | 2.63 | 57.82 | 4 55 | 5.32 | 2.67 | 8.77 |
| 8 | 20 | 108 | ... | .02 | 1.48 | 3.13 | 59.62 | 4.48 | 5.57 | 2.58 | 8.15 |
| 11 | 20 | 108 | 76 | .02 | 1.37 | 2.70 | 57.07 | 4.60 | 5.96 | 2.69 | 9.37 |
| 12 | 20 | 108 | 114 | .02 | 1.29 | 2.93 | 56.56 | 4.83 | 6.04 | 2.70 | 8 51 |
| 30[1] | 30 | 108 | 38 | .07 | 1.32 | 2.75 | 60.32 | .... | .... | .... | 8.46 |
| 18[2] | 48 | 112 | 144 | .14 | 1.34 | 3.30 | 59.26 | 4.51 | 5.69 | 2.47 | 9.35 |
| a | 112 | 81 | 103 | .15 | 1.53 | 3.44 | 59.44 | ... | .... | .... | 8.90 |

0 Unfertilized.
[1] Phosphorus and potassium supplied by tankage containing 6 percent nitrogen and 6 percent phosphorus.
[2] The three elements supplied by barn yard manure, 8 tons on corn and 8 tons on wheat.
a Elements supplied by 10 tons of manure, with addition of 400 pounds of untreated rock phosphate for the corn crop; and a fertilizer, composed of steamed bone meal 100 pounds; acid phosphate 130 pounds; potassium chloride 20 pounds; sodium nitrate 50 pounds, on the soil prepared for wheat. The sodium nitrate is applied broadcast over the wheat in April.

Aside from the variation in starch content the different fertilizer treatments have not effected the amounts of the other constituents in this group. The sugars serve the purpose of furnishing food for yeast and as a source of carbon dioxide.

The results show that a small amount of sugar was present in the wheat when analyzed, about 1.5 percent, mostly sucrose.

The amount of starch present is of no special significance except as considered in relation to the protein content.

## SUMMARY

Although differences in climate and season cause greater variations in the character of wheat than soil and fertilizers, the results obtained show that changing the chemical condition of the soil by the addition of fertilizers has produced marked differences in the same variety of wheat.

Wheat grown on unfertilized soil, where the smallest yield of grain was obtained, contained 50 percent of shriveled kernels.

Increasing the nitrogen content of the soil accentuates the above condition.

Potassium has increased the proportion of plump kernels, although the yield is the same as when nitrogen is applied to the soil and the composition is practically the same as that found in the wheat from unfertilized soil.

Phosphorus improves the physical appearance of the grain to the greatest extent.

The protein, carbohydrate and phosphorus content of the wheat grain bear a complementary relation to each other. There is an inverse ratio between the percentages of protein and carbohydrates. The phosphorus and carbohydrates stand in a direct ratio to each other. The largest percents of phosphorus and carbohydrates are found in the best developed grain, which is in turn associated with the highest yields.

The percentage of protein is highest in wheat grown on soi deficient in phosphorus and well supplied with available nitrogen.

The relation between the carbohydrates and phosphorus on the one hand and protein on the other is influenced by the form in which the nitrogen is supplied, whether from organic or inorganic sources and by the ratio of phosphorus to nitrogen.

The ratio of phosphorus to nitrogen in the wheat grain generally stands in the same order as the ratio of phosphorus to nitrogen supplied to the soil.

The percents of gluten and gliadin stand in a direct relation to the total protein content of the wheat.